CHM 1470

Oakland University
Department of Chemistry

Accuracy and Precision

Introduction

Every experimental measurement should include a number and a unit. The digits reported in a measurement are called significant figures; all digits known with certainty and one estimated digit. The measuring devices used in the laboratory determine the number of significant figures and the unit that is reported. In chemistry, the glassware used contributes to the number of significant figures reported for the raw data and the calculated values that are derived from the experimentally determined measurements. Most errors in data collection are due to human error, not necessarily from the instrument. Therefore, Knowledge of how to properly use and read the different glassware available is key to good experimental results.

With every measurement made, there are two questions that should also be considered, "How close is the measurement to the "true" value?" and "Will a similar value be produced if the measurement is repeated?" These two questions are directly related to the accuracy and precision of scientific measurements.

Accuracy describes how a measurement differs from its "true" value and it is often characterized by the percent error:

$$\text{Percent error (\%)} = \left|\frac{\textit{measured value} - \textit{true value}}{\textit{true value}}\right| \times 100$$

The smaller the percent error, the more accurate the measurement.

Precision describes the reproducibility of the measurements; that is, **how similar repeated measurements are to each other**. Highly precise measurements produce a similar result each time the measurement is repeated. In contrast, a low precision measurement produces highly scattered results.

The accuracy and precision of a measurement must be independently considered. Just because a measurement is accurate does not mean that it is precise. Likewise, just because a measurement is precise does not mean it will always be accurate. The accuracy and precision of the measurements are influenced by the type of experimental errors that occur. An experimental error can be systematic or it can be random. A systematic error causes a measurement to have a consistent deviation from the true value. Thus, when systematic error dominates a measurement, the results can have high precision (i.e., it is very repeatable), but the measurement will always have low accuracy. An example of a systematic error is a balance that always generates masses that are 5 g lower than the true values.

Random errors do not produce a consistent deviation, instead the results will fluctuate above and below the true value. The size of the fluctuations produced by random error determines the precision of the measurement. The fluctuations produced by random error can also decrease the accuracy of a measurement; however, we expect that repeating a measurement many times dominated by random error and then calculating the mean result will increase the accuracy. This is because the positive and negative deviations caused by random error will tend to cancel each other out when the mean is calculated.

For this experiment we will focus the mean value and accuracy by calculating the mean average value and percent error.

Procedure:

PreLab Quiz– Virtual – Must be completed before lab

Various pieces of commonly used glassware will be analyzed for the properties below using quantities specific to each piece.

Analyze each piece of glassware for the following:

A. Frequency of Incremental marks
B. Minimum volume that can be measured
C. Maximum volume that can be measured
D. The number of decimal places reported in a measurement.
E. Number of significant figures that should be reported when measuring 25 mL of liquid.
F. Classification of glassware type as TD(EX) or TC(LN). ("to deliver" (TD) piece of glassware is calibrated to **dispense** specified volumes of liquid or a "to contain" (TC) calibrated to **hold** specified volumes),

Part 1

In Part 1, the student's accuracy of select pieces of laboratory glassware will be analyzed by measuring 25 mL samples of deionized water. Depending on whether the glassware is classified as a TC or TD device, the procedure used to analyze for the accuracy will differ. The following glassware will be analyzed:

1. 100 mL or 150 mL beaker
2. 50 mL graduated cylinder
3. 25 mL volumetric flask
4. 50 mL buret
5. 25 mL pipet

Procedure:

Each group should obtain a kit that will contain all necessary items that are not found in your lab drawer. Before any measurements are taken, make sure that each piece of glassware is dry. The beaker and graduated cylinder can be dried with a paper towel, but the volumetric flask cannot be dried using a paper towel. The volumetric flasks should be dry when you receive them in your kit. If they are not dry, you should exchange them for dry flasks. The volumetric pipet and buret do not need to be dry. Once all glassware is dry, initial mass measurements can be made. **Make sure to use the SAME balance for all measurements throughout Part 1.**

* Since there are a limited number of balances you should weigh your glassware, and then let others use the balance.

Show correct significant figures for masses and units for all data to receive full credit.

**Density of Water vs Temperature table available on Moodle.*

Beaker:

1. Record the mass of the empty beaker on the data page and return to your bench.
2. Record the temperature of the DI water on the data page.
3. As accurately as you can, add 25 mL of DI water to the beaker.
   For the final additions of water, use an eye-dropper to add or remove water to get the bottom of the meniscus to the desired calibration mark.
4. Record the "Mass of beaker + water" on the data page.
   Before massing the water-filled containers, make sure the outside of the glassware is dry and there are no drops of water on the inside of the container above the water. Water can be removed using a paper towel.
5. Repeat the process (steps 1 – 4) for the second trial.

Graduated Cylinder:

1. Record the mass of the empty graduated cylinder on the data page and return to your bench.
2. Record the temperature of the DI water on the data page.
3. As accurately as you can, add 25 mL of DI water to cylinder.
   For the final additions of water, use an eye-dropper to add or remove water to get the bottom of the meniscus to the desired calibration mark.
4. Record the "Mass of graduated cylinder + water" on the data page.
5. Repeat the process (steps 1-4) for the second trial.

25 mL Volumetric Flask:

Must be DRY!

1. Record the mass of the empty volumetric flask on the data page and return to your bench.
2. Record the temperature of the DI water on the data page.
3. As accurately as you can, add 25 mL of DI water to flask.
   To properly add liquid to a volumetric flask, a funnel should be used. The funnel should be removed as the liquid level approaches the calibration mark. Use an eye-dropper to add liquid to get the bottom of the meniscus aligned with the calibration mark.
4. Record the "Mass of vol. flask + water" on the data page.
5. Repeat the process (steps 1-4) for the <u>second trial</u>. You need to use the second flask from your kit for the second trial.

Done

25 mL Volumetric Pipet:

Bulbs left filled

1. Record the mass of the dry empty <u>beaker</u> on the data page and return to your bench.
2. Record the temperature of the DI water on the data page.
3. Place the tip of the pipet below the surface of the water but not touching the bottom of the container. Using the pipet bulb, draw up the water into the pipet. Draw up the water until the bottom of the meniscus aligned with the calibration mark. Take care to not draw liquid up into the pipet bulb. Tap the tip of the pipet to the inside of the container to remove any excess water from the outside of the pipet.
4. Place the pipet over the pre-weighed beaker from step 1 and slowly release the water into the beaker. Touch the tip of the pipet to the inside of the beaker to add any liquid from the outside of the pipet. Remember: the pipet is calibrated to leave a small amount of liquid in the tip.
5. Record the "Mass of beaker + water" on the data page.
6. Repeat the process (steps 1-5) for the <u>second trial</u>. You will use the same pipet.

Buret:

Done

Numbered upside down

1. Record the mass of a dry empty beaker on the data page and return to your bench.
2. Record the temperature of the DI water on the data page.
3. Ensure the stopcock on the buret is closed. Fill the buret with DI water. The volume does not need to be adjusted to exactly 0.00 mL as long as you have more than 25 mL of water in the buret.
4. Record the volume of the buret as the initial volume on the data page. The volume should be recorded exactly as the graduation mark displays.
   Pre-determine the final volume measurement needed on the buret to deliver 25 mL. (Add 25.00 mL to the initial volume)
5. Place the pre-weighed beaker underneath the buret.
6. Turn the stopcock to dispense the water into the beaker. As you approach the predetermined volume, add water dropwise.
7. Record the final volume of the buret on the data page.
8. Record the "Mass of beaker + water" on the data page.
9. Repeat the process (steps 1-8) for the <u>second trial.</u>

Calculations need to be completed before leaving the lab:

1. The mass data needs to be converted to volumes using the density of water at the given temperature. The temperatures for which the density of water values is provided on Moodle and you should use the density which corresponds with nearest measured temperature values recorded.
2. Record the calculated volumes for each piece of glassware on page 8.
3. Show a sample volume calculation using Beaker #1 data on page 8.

In the normal data collection process, entire experiments are completed and then repeated for the accuracy and precision of experimental results. The data collected by each group in the lab will be used for Part 2. To investigate the accuracy of the common glassware used in the lab, the mean and % error for each piece of glassware will be calculated using your group data.

Data Analysis

Part 2

Enter your group data (all trials for each piece of glassware) from Part 1 into an Excel spreadsheet. Use the appropriate Excel functions to determine the mean. You will not use a calculator to calculate the mean or % error. All calculations will be done using Excel. Use the Excel functions – "AVERAGE" for the mean and a formula for the % error. *Print out the Excel spreadsheet and include it in your lab report after you have completed all calculations* outlined below using Excel.

Estimate the accuracy of each piece of glassware by calculating the percent error in measurements of 25 mL samples. The "true volume" is 25 mL (*the number of significant figures is dependent on the piece of glassware*) and the mean volume of water is the average value calculated using the compiled class data.

Constructing an Excel spreadsheet

Use your and your partners collected data and model your spreadsheet as close as possible to the example in Figure 1. Enter Excel calculated results in Table 3. Note, your spreadsheet will only have 4 trials.

	A	B	C	D	E	F
1						
2	Group #			Volume of Water (mL)		
		100 mL Beaker	100 mL Grad Cylinder	25 mL Vol Flask	50 mL Buret	25 mL Vol Pipet
3	1	24.515	24.651	24.911	24.925	24.912
4	2	24.224	24.454	24.895	24.918	24.954
5	3	24.675	24.734	24.922	24.899	24.875
6	4	24.321	24.425	24.915	24.925	24.912
7	5	24.121	24.579	24.905	24.925	24.926
8	6	24.453	24.485	24.914	24.929	24.918
9	7	24.895	24.678	24.908	24.915	24.875
10	8	25.224	24.712	24.916	24.912	24.944
11	9	24.116	24.553	24.909	24.918	24.923
12	10	24.287	24.619	24.91	24.922	24.917
13	Mean	24.4831	24.589	24.9105	24.9188	24.9156
14	Percent Error	2.0676	1.644	0.358	0.3248	0.3376

Figure 1. Example Excel spreadsheet for finding actual volumes of 25 mL samples of water

Pre-Laboratory Exercise

1. Review the common laboratory glassware and the techniques associated with the glassware used in this experiment found in the **Laboratory Skills** document in Moodle. This document will help you understand sig figs for volumetric glassware.

2. Complete the prelab quiz posted on Moodle. **Each** partner must complete the prelab quiz on their own.
   *Examples of a few pieces of glassware will be given in a tutorial posted on Moodle.

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Part 1 – Table 1

Name: Manideep Thalla   Partner's Name: Blake + Aiden

Piece of Glassware	Partner 1 Trial #1	Partner 1 Trial #2	Partner 1 Water Temperature	Partner 2 Trial #1	Partner 2 Trial #2	Partner 2 Water Temperature
100 or 150 mL beaker (circle the one you used)						
Mass of Beaker	57.188 g	57.145 g	~~21°C~~ 21.0°C	57.140 g	57.144 g	21.0°C
Mass of Beaker + Water	85.713 g	86.245 g		90.184 g	84.051 g	
50 mL Graduated Cylinder						
Mass of graduated cylinder	67.397 g	67.390 g	~~21°C~~ 21.0°C	~~67.390'~~ 66.~~4~~419 g	66.848 g	21.0°C
Mass of grad cylinder + water	91.636 g	91.470 g		91.103 g	91.260 g	
25 mL Volumetric Flask						
Mass of volumetric flask	23.171 g	22.664 g	~~21°C~~ 21.0°C	22.454 g	22.343 g	21.0°C
Mass of vol. flask + water	48.116 g	27.498 g		47.278 g	47.205 g	
25 mL Volumetric Pipet						
Mass of beaker	57.165 g	57.141 g	21.0°C	57.230 g	57.157 g	21.0°C
Mass of beaker + water	82.052 g	81.943 g		82.059 g	82.003 g	
50 mL Buret						
Mass of beaker	57.170 g	57.184 g	21.0°C	57.147 g	57.141 g	21.0°C
Initial Buret Reading	0.00 mL	0.05 mL		0.00 mL	0.00 mL	
Final Buret Reading	25.05 mL	25.03 mL		25.00 mL	25.13 mL	
Total Volume (final – initial)	25.05 mL	24.98 mL		25.00 mL	25.13 mL	
Mass of beaker + water	81.711 g	81.77 g		81.865 g	81.942 g	

$D = \frac{M}{V}$

Density of water $= 0.98g/mL$

BE

Name: Manideep Thalla   Partner's Name:

Table 2 - Calculations

Piece of Glassware	Partner 1		Partner 2	
25 — **100 or 150 mL beaker**	Trial #1	Trial #2	Trial #1	Trial #2
Mass of Water	28.525g			
Volume of Water	28.582mL			
Percent Error				
25.0 — **50 mL Graduated Cylinder**	Trial #1	Trial #2	Trial #1	Trial #2
Mass of Water				
Volume of Water				
Percent Error				
25 — **25 mL Volumetric Flask***	Trial #1	Trial #2	Trial #1	Trial #2
Mass of Water				
Volume of Water				
Percent Error				
25 — **25 mL Volumetric Pipet***	Trial #1	Trial #2	Trial #1	Trial #2
Mass of Water				
Volume of Water				
Percent Error				
25.00 — **50 mL Buret***	Trial #1	Trial #2	Trial #1	Trial #2
Mass of Water				
Volume of Water				
Percent Error				

***If your percent error is greater than 2 % on any of the noted pieces of glassware, you should repeat your trials until the percent error is less than 2%**

Sample volume calculation for beaker trial #1 of either partner's data. Show all work (calculation set-up) for full credit.

1. Calculate the mass of water in the beaker. Trail #1

$85.713g - 57.188g = \underline{28.525g}$

~~28.525g/0.9~~

2. Calculate the volume of water in the beaker.

$28.525g / 0.997992g/mL = \underline{28.582mL}$

3. Calculate the percent error

$\frac{28.582 - 25}{25} = $ 0.14328 = 14.328% ~~0.~~ 14% error

Name:____

Lab Partner's Name:____

Post-Laboratory Exercise

1. Which of the following sets of measurements whose true values are (A) 18.5 mL, (B) 20.0 g and (C) 55.25 mmHg, respectively, is most accurate and which is most precise? **Show any work that supports your answer.**

A.		B.		C.	
	17.2 mL		20.2 g		50.04 mmHg
	19.5 mL		19.8 g		49.98 mmHg
	18.8 mL		20.3 g		50.08 mmHg

Most Accurate______________________ Most Precise______________________

2. For the questions below (a – d), identify which general piece of glassware analyzed in this experiment is the most appropriate for the scenario described.

   a. If you were asked to add 50 mL of a stock solution to a reaction vessel, which piece of glassware would you use to obtain this volume of solution, explain?

   b. If you are told to get approximately 100 mL of a stock solution that will be used to prepare smaller size samples of that solution for an experiment, which piece of glassware would you use, explain?

   c. If you need to titrate a solution using 27.50 mL of a solution, which piece of glassware would you use to deliver this volume and explain how you would determine if the 27.50 mL was measured, explain?

d. Which piece(s) of glassware can you obtain hundredths digit accuracy?

3. What 2 pieces of glassware should you use to make an accurate solution? Example: You need to make 25.00 mL of a 0.100 M solution from a 1.00 M solution. Explain.

4. Using your data, answer the following questions

a. Which piece of glassware is the least accurate using the collected data?

b. Looking at the data for the volumetric flask, volumetric pipet and the buret, which piece of glassware has the lowest accuracy?

c. Would you contribute the low accuracy from question 4 (b) to the piece of glassware or the user? Explain.

5. What does each value (3) represent in the writing found on this volumetric pipet?